ENGINEERING CONCEPTS: Relationship Between Hardness and Strength

by Dave VanAken
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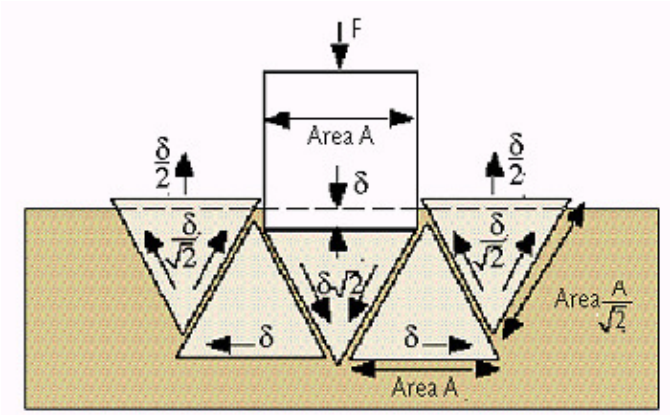


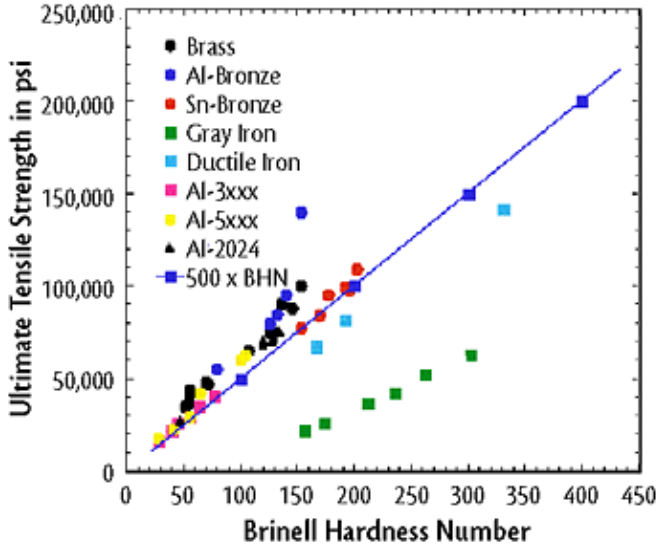
Schematic diagram used in the analysis of the hardness indentation. The five triangular portions of the material being tested slip relative to each other, thus performing work under the applied load. Figure adapted from M.F. Ashby and Dr. H. Jones, Engineering Materials 1: an introduction to their properties and applications, Butterworth/Heinemann.

Hardness tests often are used to quantify strength and are considered to be nondestructive in most applications because the indentations are small and do not adversely affect surface quality. In the case of steel, there is a common relationship between the Brinell hardness number (BHN) and the ultimate tensile strength (UTS) given in pounds force per square inch (psi), or MPa:

$$\sigma_y(psi) = \frac{1}{3} BHN\left(\frac{kg}{mm^2}\right) \times 9.807 \times 10^6 \left(\frac{Pa \cdot mm^2}{kg}\right) \times \frac{1}{6.895 \times 10^3}\left(\frac{psi}{Pa}\right) = 474 BHN$$

Using the required conversion factors to obtain units of psi yields the following equation:

The downfall of this analysis is that metals work-harden during the indentation and, as a result, the hardness correlates much better with the ultimate tensile strength rather than the yield strength. If the metal did not work harden, the indenter in Fig. 1 would penetrate through the entire thickness of the specimen by displacing the triangles.



A compilation of ultimate tensile strength versus Brinell hardness number for selected metals based on handbook data.

limited in tensile strain, or elongation, but not as severely as gray irons because the graphite is nodular rather than flake. Resulfurized steel would behave in a manner similar to that of ductile vs. gray irons, when compared with plain carbon steel.

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